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Amphibians and reptiles of the Atlantic Forest in Recôncavo Baiano, east Brazil: Cruz das Almas municipality

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Abstract

A list of amphibian and reptile species that occur in open and forested areas of the Atlantic Forest in the municipality of Cruz das Almas, in the Recôncavo Baiano, eastern Brazil is presented. Field sampling occurred between January 2015 to March 2019, totalling 117 samples distributed in three areas: Parque Florestal Mata de Cazuzinha, Mata da Cascalheira, and Riacho do Machado. A total of 1,848 individuals of 69 species (31 anurans, 14 lizards, 19 snakes, two amphisbaenians, and three testudines) was recorded. Additionally, one individual of *Ophiodes striatus* was found in Mata da Cascalheira after the end of sampling, totalling 15 lizard species and 70 herpetofaunal species. The prevalence of open-area species and the presence of *Phyllopezus lutzae*, *Diploglossus lessonae*, and *Dryadosaura nordestina* in interior forest patches are discussed. Additionally, a new record of the invasive terrapin *Trachemys dorbigni* in the State of Bahia is reported.

Keywords

Amphisbaena, anuran, diversity, lizards, species richness, snakes, testudines

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Introduction

The Atlantic Forest is a biome that occupies the entire east of South America and of Brazil and is considered one of the most diverse in species richness and levels of endemism (Mittermeier et al. 2004). Regarding amphibians, ca. 625 species occur in this biome, representing more than 50% of the species recorded in Brazil (Haddad et al. 2013; Rossa-Feres et al. 2017; Segalla et al. 2019), while for reptiles, the richness is ca. 312 species, representing 39.2% of the species that occur in the country (Tozetti et al. 2017; Costa and Bérnils 2018). The high species richness in the Atlantic Forest may be associated with a combination of factors such as latitudinal variation (encompassing tropical and subtropical areas), longitudinal variation (with marked variations in rainfall and humidity), elevational variation and biogeographic history, which have shaped different phyto-physiological units and high environmental heterogeneity (Rossa-Feres et al. 2017), reflecting patterns of richness and diversity within well-defined biogeographic units (Vasconcelos et al. 2014; Moura et al. 2017).

Despite its high richness, Brazil is also a country with high levels of threat to biodiversity. According to the Brazil Red Book of Threatened Species of Fauna (ICMBio 2018), 1,173 species are included in some threat category, including 41 species of amphibians and 80 species of reptiles. For the Atlantic Forest, this scenario is extremely worrying. Considered one of the most threatened hotspots in the world (Mittermeier et al. 2004), the biome has 37 endemic anuran species and 39 reptile species included in the list of threatened species (ICMBio 2018). The main reasons for this high rate are the intense activities related to farming and urban growth, which are responsible for causing major changes in the natural landscape (Rodrigues 2005; Silvano and Segalla 2005; ICMBio 2018). According to data from Rezende et al. (2018), only 28% of the Atlantic Forest maintain its original cover, and these areas represent small, isolated forest fragments in a matrix of pasture, plantation or anthropogenic construction; this scenario can have a catastrophic effect on gene flow and biodiversity maintenance.

The State of Bahia is a state with great richness of herpetofauna species (Hamdan and Lira-da-Silva 2012; Dias and Rocha 2014; Freitas et al. 2019). Although in recent years many studies have been developed to characterise the herpetofauna of this state (see Freitas et al. 2016a, b, 2018; Gondim-Silva et al. 2016; Marques et al. 2016; Mira-Mendes et al. 2018; Leite et al. 2019; Souza-Costa et al. 2020; Rojas-Padilla et al. 2020), the vast majority of these initiatives were limited to investigations in specific regions, especially areas of dense ombrophilous forest in the south and southeast of the state (Argôlo 2004; Camurugi et al. 2010; Dias et al. 2014a; Mira-Mendes et al. 2018; Rojas-Padilla et al. 2020; Souza-Costa et al. 2020), sand dune areas on the northern coast of the state (Tinôco et al. 2007; Dias and Rocha 2014; Gondim-Silva et al. 2016; Marques et al. 2016; Napoli et al. 2017) and high-elevation regions of Chapada Diamantina (northern portion of Serra do Espinhaço) (Leite et al. 2008; Xavier and Napoli 2011; Freitas et al. 2012; Magalhães et al. 2015). Allied to this, many of these studies were carried out within protected areas (Leite et al. 2008; Camurugi et al. 2010; Freitas et al. 2012; Garda et al. 2013; Dias et al. 2014a; Magalhães et al. 2015; Mira-Mendes et al. 2018; Rojas-Padilla et al. 2020), high-

lighting information gaps on the herpetofauna of unprotected areas, making it difficult to identify new areas of ecological relevance.

The Recôncavo Baiano is a region located in the eastern portion of the State of Bahia, corresponding to the portion of land that lies around Todos os Santos Bay (Azevedo 2011). The region has great historical, cultural, and economic importance, standing out for its sugarcane production during the colonial period and, more recently, for its industrial production of petroleum, as well as tobacco and citrus fruits (Sansone 2011). This history of its spatial use was accompanied by intense vegetation suppression and a reduction in original vegetation cover levels. According to data from the Economic-Ecological Zoning of the State of Bahia (Seplan 2015), a management instrument aimed at guiding the use of natural resources, a large part of the Recôncavo Baiano is inserted in the zone called "Tabuleiros Interioranos do Recôncavo" (Interior Trays of the Recôncavo), and only 9.3% of this zone contain the original vegetation cover, although 30% represent a priority area for conservation, revealing alarming levels for biota conservation.

Although a large part of the Recôncavo Baiano is located in the Atlantic Forest, studies characterising the herpetofauna of this region have been conducted almost exclusively in Serra da Jibóia and Serra do Timbó, which represent a set of mountains (elevational range 660–900 m above sea level, respectively) disjoined in the eastern portion of Serra do Espinhaço, in transition with the Caatinga (Juncá 2006; Cruz et al. 2008; Cruz and Napoli 2010; Freitas et al. 2018; Freitas et al. 2019). Furthermore, Freitas (2014) sought to characterise the Atlantic Forest snake fauna of eastern Bahia, including the Recôncavo Baiano; however, despite revealing a high richness of species, his study did not present systematic or standardised searches in the 29 municipalities analysed, which resulted in a sub-sampling in the central portion of the Recôncavo Baiano, including the "Tabuleiros Interioranos".

This panorama reinforces the appeal for increased studies in forested and open areas of eastern Bahia to improve the characterisation of the richness and species composition of the herpetofauna of this portion of the Atlantic Forest. This information is essential to identify and monitor population fluctuations, enabling an accurate diagnosis of the ecosystem's integrity and allowing access to the mechanisms that are involved in generating the region's fauna diversity. In this study, we present a list of amphibian and reptile species that occur in open and forested areas of the municipality of Cruz das Almas, as part of a long-term project that seeks to characterise the herpetofauna of all the municipalities that are part of the Recôncavo Baiano, to minimise differences in the sample efforts along the different regions of the Atlantic Forest and to fill the information gaps regarding the state fauna.

Materials and methods

Study area

The study was conducted in Cruz das Almas municipality, Bahia State, in northeast Brazil (12°40'25"S, 39°06'05"W) (Figure 1). Cruz das Almas is located in the east-

ern portion of Bahia State and inserted in the region of the Recôncavo Baiano, in the Atlantic Forest biome. The region is characterised by original vegetation of Semideciduous Seasonal Forest (Brazão and Araújo 1981); however, it has been almost completely replaced by grazing areas for cattle raising and by plantations. According to the Köppen classification, the climate is tropical monsoon (Am), with an average temperature of 23.9 °C and an annual rainfall of 1,131.2 mm (Silva et al. 2016). Cruz das Almas is located in the area "Tabuleiros Interioranos do Recôncavo" (Interior Trays of the Recôncavo), characterised by a flat and gently undulating top relief, not exceeding 200 m in elevation, in addition to a large amount of micro-basins, which is propitious for agricultural production. Only 5% of the "Tabuleiros Interioranos do Recôncavo" area are inserted in some conservation units, all of them of sustainable use (Seplan 2015).

Field activities were concentrated in three areas of the municipality that presented good conservation status and potential for finding herpetofauna specimens (Figure 2):

(i) Parque Florestal Mata de Cazuzinha (12°39'58"S, 39°06'25"W; elevation 235 m): This is a forest fragment of ca. 20 ha, inserted in an urban matrix. It is considered an area of secondary vegetation, but presents a homogeneous and dense aspect, with predominance of arboreal vegetation of medium and large size. There is no evidence of permanent waterbodies inside the Cazuzinha forest, yet it has a forest structure that enables moisture concentration. Because it is located in an urban environment, the Cazuzinha forest suffers great anthropic pressure associated with hunting, wood removal and waste deposit. The area is intensely frequented by the local population for leisure activities.

(ii) Riacho do Machado (12°40'35.89"S, 39°25'59"W; elevation 226 m): The largest forest patch fragment in Cruz das Almas municipality. It is located between the experimental area of the Empresa Brasileira de Pesquisas Agropecuárias (Brazilian Agricultural Research Corporation) and the campus of the Federal University of Recôncavo da Bahia. This area is inserted in a hillside region and has medium-sized trees. It has a central lake ca. 5 m deep and a stream that names the patch. The homogeneous aspect of the vegetation indicates that the area has not been much accessed for wood removal, probably due to the difficulty of access. Nevertheless, during this study, some actions of burning, cutting and timber extraction were witnessed. Inside the forest, there are regions of "swamps", which are propitious environments for the reproduction of anurans, as well as regions with rocky outcrops.

(iii) Mata da Cascalheira (12°39'29"S, 39°04'48"W; elevation 212 m): Cascalheira forest patch is an area of secondary forest, with predominance of shrubby vegetation and grasses. The forest patch is inserted in a region of hillsides and has a lagoon in the central region, which is ca. 4 m deep and contains large amounts of cattail and macrophytes. Mata da Cascalheira is inserted in the campus of the Federal University of Recôncavo da Bahia, which is a benchmark in agricultural studies. Thus, much of the patch has already been used as pastureland or arable land, with the formation of small puddles during rain events. In addition, it is possible to find

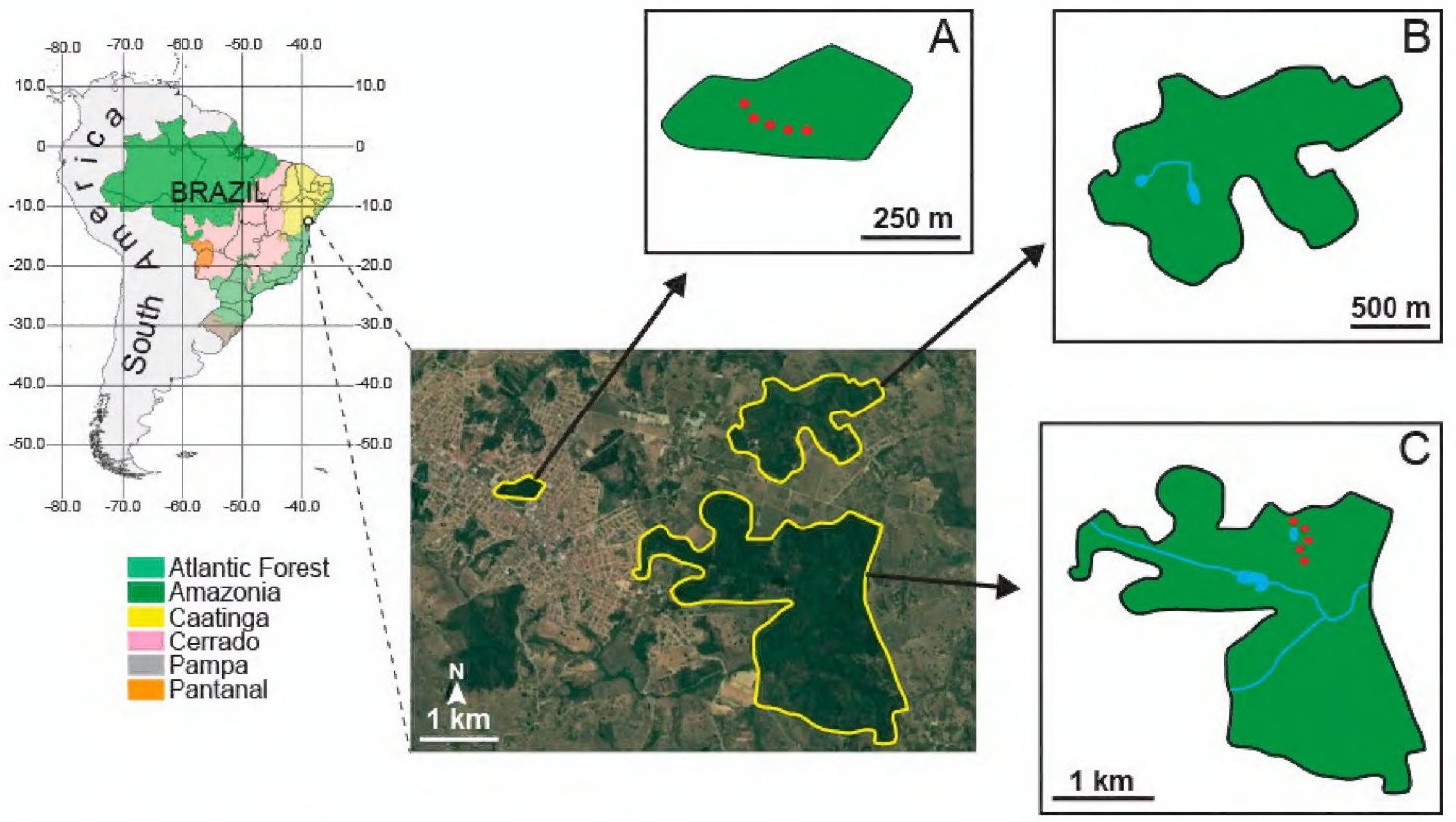

Figure 1. Geographical location of the Cruz das Almas municipality and areas of study **A** Parque Florestal Mata de Cazuzinha **B** Mata da Cascalheira **C** Riacho do Machado. Red dots represent localisation and disposition of the pitfall traps.

some houses near the forest patch, where the residents engage in subsistence farming activity. Some areas of the Mata da Cascalheira were used for the extraction of land and stones for construction.

Data collection

We conducted the field activities from January 2015 to Mach 2019, through non-standard day and night collections in the three different areas, totalling 117 samples. All daytime collections started at 8 am and ended at 5 pm, while night-time collections started at 6 pm and ended at midnight. The collections were performed by at least three and at most eight researchers. To collect the specimens, we used the techniques of visual encountering through random search inside and around the patches, aided by shot guns, and the places investigated were holes, burrows, tree trunks, fallen trunks, the interior of bromeliads, rocks, and all microhabitats conducive to the encounter of individuals in shelter or in activity (Figure 2A–E). For amphibians, we also used the acoustic search to find males in vocalisation activity, concentrating the activities around the waterbodies (Heyer et al. 1994). To enhance the encounter of herpetofauna specimens, we installed five pitfall traps in each area. The traps were arranged in a Y-shape, with four 30-L buckets connected by three 8-m drift fences build with plastic sheets (Figure 2F). The stations were ca. 60 meters apart and remained installed for 32 days in each area; they were inspected daily. The pitfall traps were not efficiently implemented in the Mata da Cascalheira due to the strong human presence, with consequent damage to the buckets, which made it impossible to use

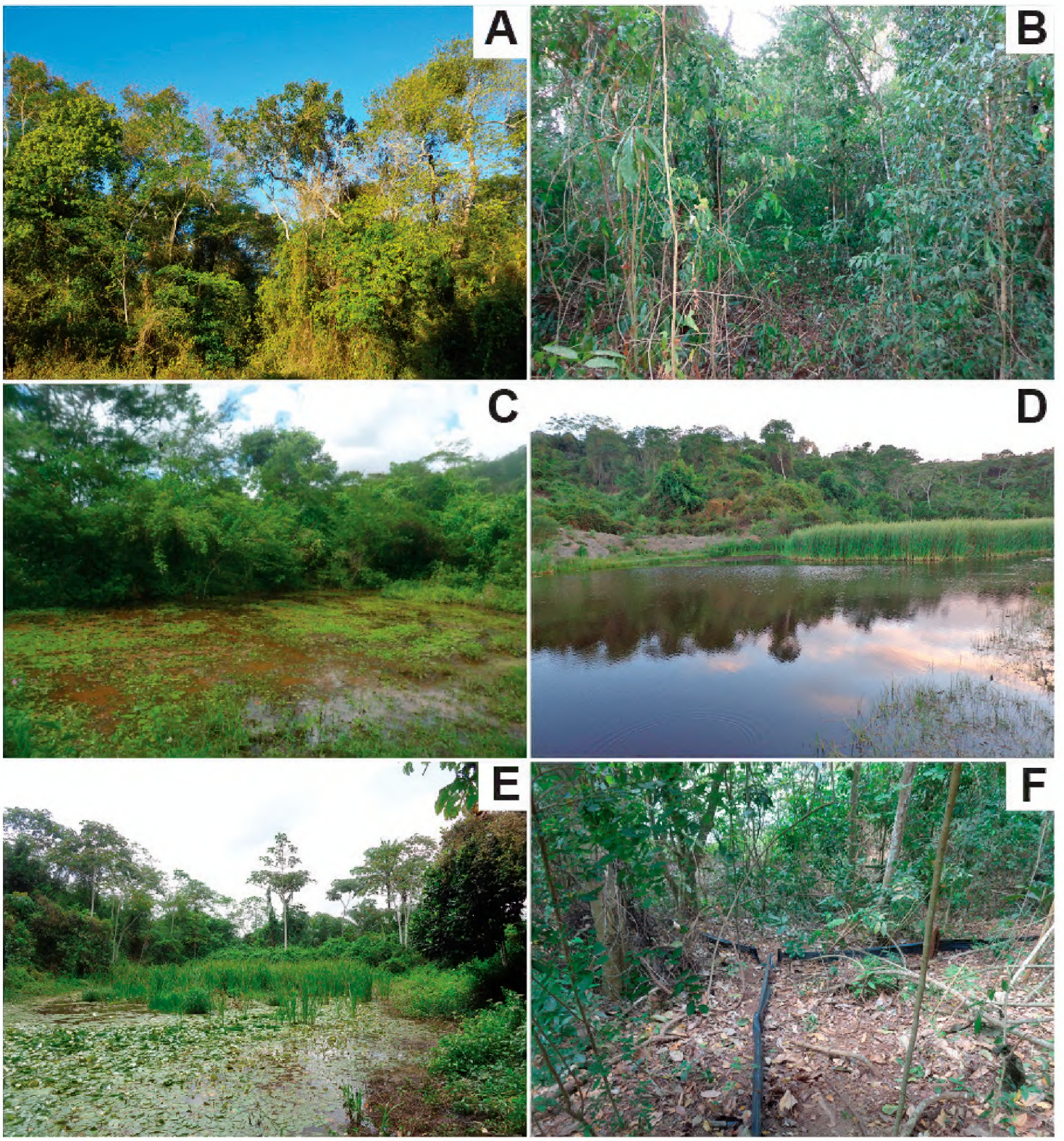

Figure 2. Habitats sampled during the field works **A** view of Mata de Cazuzinha showing tall trees and shrubs **B** inside the Mata de Cazuzinha **C** temporary pond in Mata da Cascalheira **D** lagoon in Mata da Cascalheira **E** temporary pond in the Riacho do Machado **F** pitfall trap in the interior of the forest at Riacho do Machado.

the traps on site. Nevertheless, as we did not seek to perform a comparative analysis between the areas but rather to summarise the species of the herpetofauna found in the region, this scenario did not interfere with our objectives. In addition, we also employed the techniques of occasional encounters and encounters by third parties to better characterise the herpetofauna.

All animals collected were euthanised via intraperitoneal injection of 2% lidocaine, fixed in 10% formaldehyde, preserved in 70% alcohol, and deposited in the Herpeto-

logical Collection of the Universidade Federal do Recôncavo da Bahia (Sisbio Permit 46558-1 and 46558-2; CEUA-UFRB Permit 23007.007559/2016-71). The animals collected had a small fragment of the liver extracted to create a genetic database of the herpetofauna of the Recôncavo Baiano region, providing support for future studies.

Analyses

To evaluate the quality of our sampling effort, we used the data of species richness and abundance of individuals to produce rarefaction curves (1,000 randomisations), using the ESTIMATES 9.1.0 program (Colwell 2013). Since our samples from non-standard samples, we used the individual based curve to standardise our effort, as each sample unit is an individual. Subsequently, the observed richness was compared with the estimated richness from the non-parametric estimators Bootstrap, Chao 2 and Jackknife 1 and 2 (Magurran 2004). As these estimators are sensitive to singletons and doubletons, species with low abundance were inserted in analyses. We built a rarefaction curve for amphibians, a rarefaction curve for lizards, a rarefaction curve for snakes and a rarefaction curve joining all groups (herpetofauna), including amphisbaenians and testudines. In addition, we verified which species are typical of the Atlantic Forest, based on Rossa-Feres et al. (2017) and Tozetti et al. (2017), for amphibians and reptiles, respectively.

Finally, we compared the similarity of the species composition of the amphibian and reptiles of Cruz das Almas with the species composition of other assemblages of the Brazilian Atlantic Forest. We performed an analysis considering only anurans, lizards, and snakes. Data on the composition of anurans from other assemblages were obtained from 32 studies, while data on the composition of lizards and snakes were obtained from 21 studies. For this, we subdivided the Atlantic Forest into four biogeographic sub-regions, based on Silva and Casteleti (2003) to identify regional similarities: (1) north of the São Francisco River, covering the states of Paraíba (PB), Pernambuco (PE), and Rio Grande do Norte (RN) – Mata do Buraquinho (Santana et al. 2008); Macaíba (Magalhães et al. 2013); Boca da Mata (Palmeira and Gonçalves 2015); Serra do Urubu (Roberto et al. 2017); Reserva Biológica (REBIO) Guaribas (Mesquita et al. 2018); (2) south of the São Francisco River, covering the states of Bahia (BA) and Sergipe (SE) – Mata de São João (Couto-Ferreira et al. 2011; Marques et al. 2011); Mata do Junco (Morato et al. 2011); Jequié (Lantyer-Silva et al. 2013); Serra Bonita (Dias et al. 2014a); Conde (Gondim-Silva et al. 2016); Serra da Jibóia (Freitas et al. 2018); Reserva Michelin (Mira-Mendes et al. 2018); Serra do Timbó (Freitas et al. 2019); Serra das Lontras (Rojas-Padilla et al. 2020); Serra Azul and Serra de Mandim (Souza-Costa et al. 2020); (3) southeast Brazil and the Serra do Mar region, covering the states of Espírito Santo (ES), Minas Gerais (MG), São Paulo (SP), and Rio de Janeiro (RJ) – Rio Novo (Feio and Ferreira 2005); Reserva Florestal (RF) de Morro Grande (Dixo and Verdade 2006); Rio Claro (Zina et al. 2007); Estação Ambiental (EA) de Peti (Bertoluci et al. 2009); Ilha de Anchieta (Cicchi et al. 2009); Parque Estadual (PE) Jurupará (Condez et al. 2009); Estação Ecológica (EE)

Juréia-Itatins (Narvaes et al. 2009); Parque Estadual Turístico (PET) do Alto Ribeira (Araujo et al. 2010); Parque Estadual (PE) Carlos Botelho (Forlani et al. 2010); Alto Rio Muriaé (Santana et al. 2010); Estação Ecológica (EE) do Paraíso (Vrcibradic et al. 2011); Serra do Brigadeiro (Moura et al. 2012); Parque Natural Municipal (PNM) de Grumari (Telles et al. 2012); Reserva Ecológica (RE) de Guapiaçu (Almeida-Gomes et al. 2014); São Roque do Canaã (Mônico et al. 2017); and (4) – south Brazil and the Araucaria Forest region, covering the states of Paraná (PR), Santa Cararina (SC) and Rio Grande do Sul (RS) – Rio Grande (Quintela et al. 2006); Parque Estadual (PE) de Itapeva (Colombo et al. 2008); Morretes (Armstrong and Conte 2010); Parque Nacional (PN) das Araucárias (Lucas and Marocco 2011); Parque Natural Municipal (PNM) de Sertão (Zanella et al. 2013). We excluded the species identified at the level of genus and those in which the authors had doubts about the specific epithet. Cluster analysis was performed using the UPGMA algorithm and Jaccard index in the Past 4.05 program (Hammer et al. 2001).

Results

We recorded a total of 1,848 individuals, distributed in 69 species of amphibians and reptiles (31 anurans, 14 lizards, 19 snakes, two amphisbaenians, and three testudines). Additionally, in December 2020, after the end sampling, we found an individual of *Ophiodes striatus* in Mata da Cascalheira, adding a lizard species to the list, totalling 15 lizard species and 70 herpetofauna species. The anurans identified belong to the families Bufonidae (3 spp.), Craugastoridae (1 sp.), Hylidae (13 spp.), Leptodactylidae (11 spp.), Microhylidae (1 sp.) and Phyllomedusidae (2 spp.) (Table 1, Figures 3, 4). The 15 species of lizards belong to the families Dactyloidae (1 sp.), Diploglossidae (2 spp.), Gekkonidae (3 spp.), Gymnophthalmidae (1 sp.), Iguanidae (1 sp.), Mabuyidae (2 spp.), Polychrotidae (1 sp.), Sphaerodactylidae (1 sp.), Teiidae (2 spp.) and Tropiduridae (1 sp.). The 19 snake species belong to the families Boidae (2 spp.), Colubridae (5 spp.), Dipsadidae (9 spp.), Elapidae (1 sp.), Typhlopidae (1 sp.) and Viperidae (1 sp.). The two amphisbaenians species belong to the family Amphisbaenidae (2 spp.), and the testudines belong to the families Chelidae (1 sp.), Emydidae (1 sp.) and Testudinidae (1 sp.) (Table 2, Figures 5–7).

The rarefaction curve approached the asymptote only for amphibians, demonstrating that the sample effort managed to obtain a satisfactory representation of species (Figure 8). However, richness estimators predicted the existence of species not yet added to the list, ranging from one to two species of anurans. For lizards, snakes, and herpetofauna, the rarefaction curves did not reach the asymptote, and the richness estimators added between one and four species, between three and 11 species, and between seven and 21 species, respectively (Table 3). The observation of the species composition of the anurans assemblage from Cruz das Almas revealed the presence of two groups of species: species endemic to the Atlantic Forest (*Rhinella crucifer*, *Pristimantis paulodutrai*, *Boana albomarginata*, *Dendropsophus branneri*, *Dendropsophus elegans*, *Dendropsophus novaisi*, *Phyllomedusa bahiana*, *Scinax auratus*, *Scinax eurydice*) and species

Table 1. Check list of amphibians identified at Cruz das Almas municipality, Bahia State.

Taxon	Species	Abundance
Anura		
Bufonidae	*Rhinella crucifer* (Wied-Neuwied, 1821)	2
	Rhinella granulosa (Spix, 1824)	24
	Rhinella jimi (Stevaux, 2002)	54
Craugastoridae	*Pristimantis paulodutrai* (Bokermann, 1975)	118
Hylidae	*Boana albomarginata* (Spix, 1824)	107
	Boana crepitans (Wied-Neuwied, 1824)	29
	Boana faber (Wied-Neuwied, 1821)	5
	Dendropsophus elegans (Wied-Neuwied, 1824)	229
	Dendropsophus branneri (Cochran, 1948)	84
	Dendropsophus minutus (Peters, 1872)	7
	Dendropsophus novaisi (Bokermann, 1968)	11
	Dendropsophus oliveirai (Bokermann, 1963)	63
	Scinax auratus (Wied-Neuwied, 1821)	46
	Scinax eurydice (Bokermann, 1968)	23
	Scinax pachycrus (Miranda-Ribeiro, 1937)	3
	Scinax x-signatus (Spix, 1824)	60
	Trachycephalus atlas Bokermann, 1966	2
Leptodactylidae	*Leptodactylus fuscus* (Schneider, 1799)	38
	Leptodactylus macrosternum Miranda-Ribeiro, 1926	100
	Leptodactylus mystaceus (Spix, 1824)	16
	Leptodactylus natalensis Lutz, 1930	24
	Leptodactylus vastus Lutz, 1930	24
	Leptodactylus troglodytes Lutz, 1926	54
	Physalaemus albifrons (Spix, 1824)	1
	Physalaemus cuvieri Fitzinger, 1826	106
	Physalaemus kroyeri (Reinhardt & Lütken, 1862)	95
	Pseudopaludicola cf. *mystacalis* (Cope, 1887)	1
	Pseudopaludicola florencei Andrade, Haga, Lyra, Leite, Kwet, Haddad, Toledo & Giaretta, 2018	16
Microhylidae	*Dermatonotus muelleri* (Boettger, 1885)	10
Phyllomedusidae	*Phyllomedusa bahiana* Lutz, 1925	13
	Pithecopus nordestinus (Caramaschi, 2006)	30

distributed in two or more biomes (*Rhinella granulosa*, *Rhinella jimi*, *Boana crepitans*, *Boana faber*, *Dendropsophus minutus*, *Dendropsophus oliveirai*, *Scinax x-signatus*, *Scinax pachycrus*, *Trachycephalus atlas*, *Pithecopus nordestinus*, *Leptodactylus fuscus*, *Leptodactylus macrosternum*, *Leptodactylus mystaceus*, *Leptodactylus natalensis*, *Leptodactylus troglodytes*, *Leptodactylus vastus*, *Physalaemus albifrons*, *Physalaemus cuvieri*, *Physalaemus kroyeri*, *Pseudopaludicola* cf. *mystacalis*, *Pseudopaludicola florencei*, *Dermatonotus muelleri*). For lizards, only *Phyllopezus lutzae* and *Dryadosaura nordestina* are endemic to the Atlantic forest, while for snakes only *Bothrops leucurus* is endemic.

The cluster analysis revealed that the assemblages of anurans, lizards, and snakes from Cruz das Almas formed close groups with those assemblages from northeast Brazil, specifically from north and south of the São Francisco River. This result indicates that there is a faunal similarity between assemblages inserted in the Central Corridor of the Atlantic Forest and the Pernambuco Endemism Centre (Figures 9–11). The anuran assemblage was more similar to the Conde assemblage, whereas the snake assemblage was more similar to the Mata do Buraquinho and REBIO Guaribas assemblages. For lizards, the Cruz das Almas assemblage was more similar to the Serra do Timbó, Serra da Jibóia, Mata de São João, REBIO Guaribas, Mata do Junco, Serra do Urubu, and Mata do Buraquinho assemblages.

Figure 3. Anuran species identified at Cruz das Almas municipality, Bahia State **A** *Rhinella crucifer* **B** *Rhinella granulosa* **C** *Rhinella jimi* **D** *Pristimantis paulodutrai* **E** *Boana albomarginata* **F** *Boana crepitans* **G** *Boana faber* **H** *Dendropsophus branneri* **I** *Dendropsophus elegans* **J** *Dendropsophus minutus* **K** *Dendropsophus novaisi* **L** *Dendropsophus oliveirai* **M** *Scinax auratus* **N** *Scinax eurydice* **O** *Scinax pachycrus*.

Discussion

The anuran species richness identified in Cruz das Almas corresponds to 5% of the anuran richness currently known for the Atlantic Forest (Rossa-Feres et al. 2017) and 2.8% of the anuran richness of Brazil (Segalla et al. 2019). Furthermore, 29% of the

Table 2. Check list of reptiles identified at Cruz das Almas municipality, Bahia State.

Taxon	Species	Abundance
Squamata		
Amphisbaenidae	*Amphisbaena alba* Linnaeus, 1758	14
	Amphisbaena vermicularis Wagler, 1824	5
Lizards		
Dactyloidae	*Norops fuscoauratus* (D'Orbigny, 1837)	9
Diploglossidae	*Diploglossus lessonae* Peracca, 1890	2
	Ophiodes striatus (Spix, 1824)	1
Gekkonidae	*Hemidactylus mabouia* (Moreau de Jonnès, 1818)	144
	Phyllopezus lutzae (Loveridge, 1941)	11
	Phyllopezus pollicaris (Spix, 1825)	50
Gymnophthalmidae	*Dryadosaura nordestina* Rodrigues, Freire, Pellegrino & Sites, 2005	1
Iguanidae	*Iguana iguana* (Linnaeus, 1758)	1
Mabuyidae	*Brasiliscincus heathi* (Schmidt & Inger, 1951)	5
	Psychosaura macrorhyncha (Hoge, 1946)	2
Polychrotidae	*Polychrus acutirostris* Spix, 1825	3
Sphaerodactylidae	*Coleodactylus meridionalis* (Boulenger, 1888)	19
Teiidae	*Ameiva ameiva* (Linnaeus, 1758	35
	Salvator merianae Duméril & Bibron, 1839	4
Tropiduridae	*Tropidurus hispidus* (Spix, 1825)	72
Snakes		
Boidae	*Boa constrictor* Linnaeus, 1758	4
	Epicrates assisi Machado, 1945	5
Colubridae	*Chironius carinatus* (Linnaeus, 1758)	1
	Erythrolamprus miliaris (Linnaeus, 1758)	1
	Erythrolamprus reginae (Linnaeus, 1758)	3
	Leptodeira annulata (Linnaeus, 1758)	1
	Tantilla melanocephala (Linnaeus, 1758)	2
Dipsadidae	*Dipsas neuwiedi* (Ihering, 1911)	3
	Helicops leopardinus (Schlegel, 1837)	1
	Pseudoboa nigra (Duméril, Bibron & Duméril, 1854)	5
	Oxyrhopus petolarius (Linnaeus, 1758)	1
	Oxyrhopus trigeminus Duméril, Bibron & Duméril, 1854	6
	Philodryas olfersii (Lichtenstein, 1823)	7
	Philodryas patagoniensis (Girard, 1858)	1
	Thamnodynastes pallidus (Linnaeus, 1758)	3
	Xenodon merremii (Wagler, 1824)	3
Elapidae	*Micrurus ibiboboca* (Merrem, 1820)	17
Typhlopidae	*Amerotyphlops brongersmianus* (Vanzolini, 1976)	3
Viperidae	*Bothrops leucurus* Wagler, 1824	6
Testudines		
Chelidae	*Phrynops geoffroanus* (Schweigger, 1812)	1
Emydidae	*Trachemys dorbigni* (Duméril & Bibron, 1835)	1
Testudinidae	*Chelonoidis carbonarius* (Spix, 1824)	1

anuran species identified in the Cruz das Almas assemblage are endemic to the Atlantic Forest (Rossa-Feres et al. 2017). The richness of Cruz das Almas anurans, when compared to other assemblages in the Atlantic Forest, revealed a value similar to those from the north and the south of the São Francisco River (Morato et al. 2011, n = 33; Lantyer-Silva et al. 2013, n = 31; Magalhães et al. 2013, n = 34; Palmeira and Gonçalves 2015, n = 32; Mesquita et al. 2018, n = 34) and higher than some assemblages from south and southeast Brazil (Feio and Ferreira 2005, n = 20; Zina et al. 2007, n = 24; Narvaes et al. 2009, n = 20; Zanella et al. 2013, n = 23). However, it was a lower value

Figure 4. Anuran species identified at Cruz das Almas municipality, Bahia State **A** *Scinax x-signatus* **B** *Trachycephalus atlas* **C** *Phyllomedusa bahiana* **D** *Pithecopus nordestinus* **E** *Leptodactylus macrosternum* **F** *Leptodactylus fuscus* **G** *Leptodactylus mystaceus* **H** *Leptodactylus natalensis* **I** *Leptodactylus troglodytes* **J** *Leptodactylus vastus* **K** *Physalaemus albifrons* **L** *Physalaemus cuvieri* **M** *Physalaemus kroyeri* **N** *Pseudopaludicola florencei* **O** *Dermatonotus muelleri*.

than those from other assemblages from southeast Brazil (Araujo et al. 2010, n = 58; Forlani et al. 2010, n = 64; Moura et al. 2012, n = 57; Almeida-Gomes et al. 2014, n = 70) and from the north of the São Francisco River (Roberto et al. 2017, n = 46). Within Bahia State, the richness of Cruz das Almas revealed a similar value to the as-

Figure 5. Reptile species identified at Cruz das Almas municipality, Bahia State **A** *Norops fuscoauratus* **B** *Diploglossus lessonae* **C** *Hemidactylus mabouia* **D** *Phyllopezus lutzae* **E** *Phyllopezus pollicaris* **F** *Dryadosaura nordestina* **G** *Iguana iguana* **H** *Brasiliscincus heathi* **I** *Psychosaura macrorhyncha* **J** *Polychrus acutirostris* **K** *Coleodactylus meridionalis* **L** *Ameiva ameiva* **M** *Tropidurus hispidus* **N** *Amphisbaena alba* **O** *Amphisbaena vermicularis*.

semblages from the southeast (Dias et al. 2014b, n = 33–40) and the northern coast (Juncá 2006, n = 25; Bastazini et al. 2007, n = 30; Gondim-Silva et al. 2016, n = 33). Conversely, this value was low when compared with some southern (Dias et al. 2014a, n = 79; Rojas-Padilla et al. 2020, n = 49) and southeast (Mira-Mendes et al. 2018, n = 68) assemblages of the state.

Figure 6. Reptile species identified at Cruz das Almas municipality, Bahia State **A** *Boa constrictor* **B** *Epicrates assisi* **C** *Chironius carinatus* **D** *Erytrolamprus miliaris* **E** *Erytrolamprus reginae* (juvenile) **F** *Leptodeira annulata* **G** *Tantilla melanocephala* **H** *Dipsas neuwiedi* **I** *Pseudoboa nigra* (juvenile) **J** *Pseudoboa nigra* (adult) **K** *Oxyrhopus petolarius* **L** *Oxyrhopus trigeminus* **M** *Philodryas olfersii* **N** *Philodryas patagoniensis* **O** *Thamnodynastes pallidus*.

According to Lantyer-Silva et al. (2013), locations within the Atlantic Forest where the richness of amphibians ranging around 32 species can be considered as having an intermediate richness, which seems to be a common pattern for assemblages of Atlantic Forest-Caatinga ecotones. These assemblages are characterised by

Figure 7. Reptile species identified at Cruz das Almas municipality, Bahia State **A** *Xenodon merremii* **B** *Micrurus ibiboboca* **C** *Amerotyphlops brongersmianus* **D** *Bothrops leucurus* **E** *Phrynops geoffroanus* **F** *Trachemys dorbigni*.

Table 3. Mean and standard deviation of the species richness estimated with different estimators in Cruz das Almas municipality. Herpetofauna represent the combination of amphibians, lizards, snakes, amphisbaenians, and testudines.

	Amphibians	Lizards	Snakes	Herpetofauna
Observed richness	31	15	19	70
Bootstrap	32 ± 0	16 ± 0	22 ± 0	77 ± 0
Chao 2	31 ± 0.62	16 ± 1.79	26 ± 8.06	81 ± 8.05
Jackknife 1	33 ± 1.39	18 ± 1.68	25 ± 2.32	84 ± 3.58
Jackknife 2	31 ± 0	19 ± 0	30 ± 0	91 ± 0
Singletons	2	3	6	14

higher species richness than the Caatinga, as well as a species composition common to both biomes (Lantyer-Silva et al. 2013). Thus, the richness and composition of species of the anurans assemblage from Cruz das Almas leads to a fauna characteristic of transition zones between the Atlantic Forest and Caatinga biomes, even though Cruz das Almas municipality is inserted into the Atlantic Forest biome. This scenario goes against our initial expectations. We expected that the Cruz das Almas assemblage would reveal a greater quantity of endemic species of the Atlantic Forest. However, the species composition was dominated by generalist species, typically associated with open lands. We did not rule out the possibility that the species composition observed in this study is associated with the history of intense land use, the accentuated suppression of vegetation and changes in the natural landscape of Cruz das Almas, which reflected the formation of secondary forest patches, as well as intense open areas destined for pasture and plantation. This remarkable anthropisation may have promoted the selection of species more tolerant to landscape changes, as well as the extinction of species more specialised in forest habitats, causing a reduction in richness (Almeida-Gomes and Rocha 2014). However, studies that seek to verify the variation in species

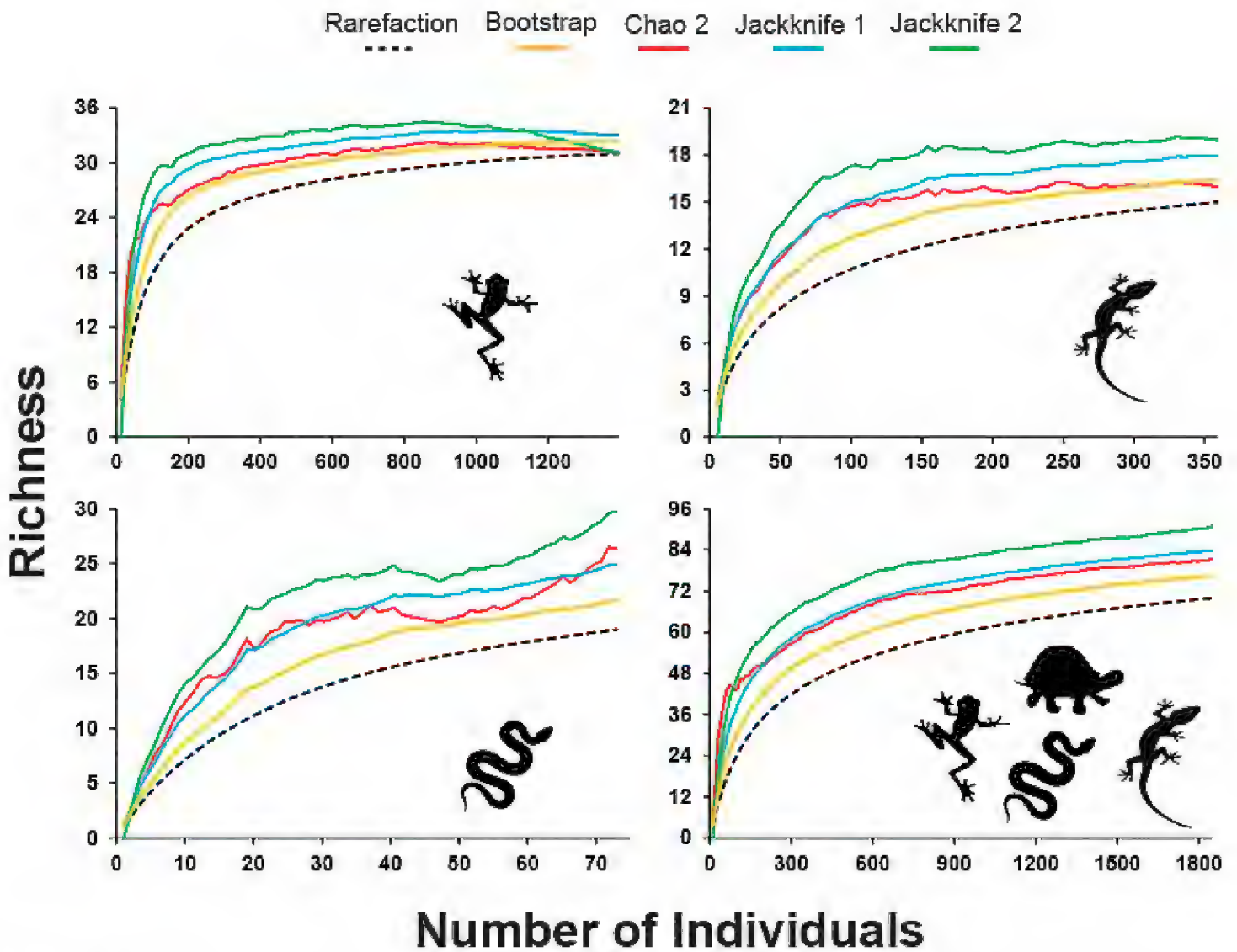

Figure 8. Species rarefaction curves and richness estimators for amphibians, lizards, snakes and herpetofauna collected at Cruz das Almas municipality. Herpetofauna represent the combination of amphibians, lizards, snakes, amphisbaenians, and testudines.

composition between areas with different levels of conservation in this region could better clarify this assumption.

None of the anuran species found in our study revealed an unusual or unexpected record for the region, having been previously reported for the State of Bahia and the Atlantic Forest (Dias et al. 2014a; Gondim-Silva et al. 2016; Freitas et al. 2018; Mira-Mendes et al. 2018; Freitas et al. 2019). Nevertheless, we report a new record of the recently described *Pseudopaludicola florencei* for Bahia State. Besides the locality type (Andaraí, Bahia), the species has been recognised in only two localities (Mutuípe, in the State of Bahia and Nanuque, in the State of Minas Gerais) (Andrade et al. 2018). In Cruz das Almas, *P. florencei* was observed vocalising in small puddles or fillets of water formed after the first rains, always in open areas near Riacho do Machado and Mata da Cascalheira. The species was identified on the basis of morphological and acoustic characteristics, consistent with the original description. Thus, we believe that a more accurate analysis of the advertisement call of other individuals of the genus *Pseudopaludicola* can reveal the presence of the species in other localities of the Atlantic Forest of the east of Bahia.

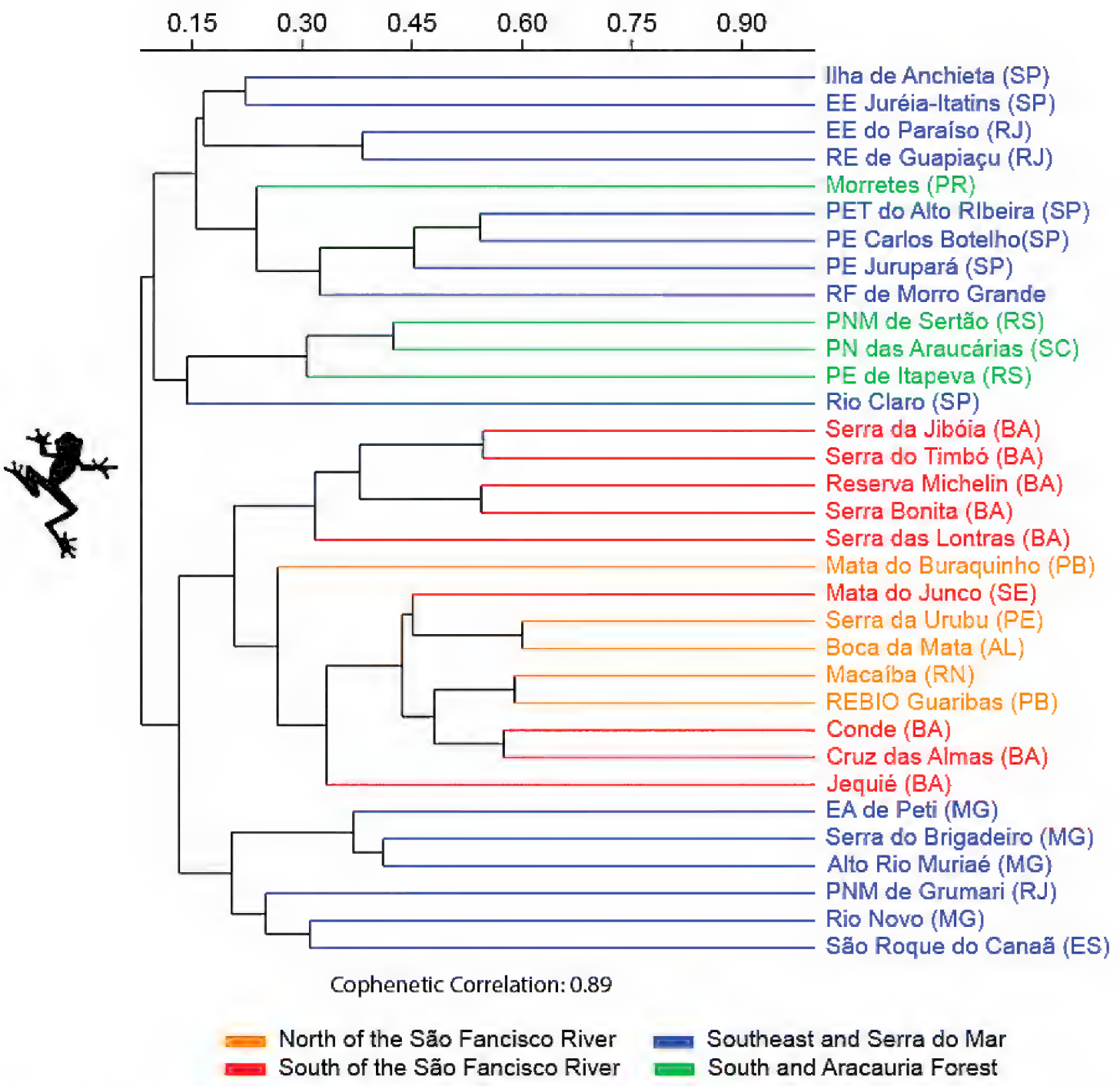

Figure 9. Dendrogram of cluster analysis (Jaccard Indices) of the anuran species composition from 33 localities in Brazilian Atlantic Forest. Abbreviations in Materials and methods.

The Cruz das Almas assemblage presented a low number of typical species from forested areas and prevalence of typical species from open land. This result explains the greater similarity of the Cruz das Almas assemblage with other assemblage from open land and Atlantic Forest-Caatinga ecotones observed in our cluster analysis. Anthropic actions may have shaped the current pattern of the Cruz das Almas assemblage, leading to the reduction of species more specialised to forest habitats. This scenario reveals the need for greater efforts to preserve the remaining forest fragments in the region. Nevertheless, *Pristimantis paulodutrai* was the dominant species in the interior of forest fragments in Mata de Cazuzinha, often found vocalising perched on herbaceous vegetation. Besides *P. paulodutrai*, only *Rhinella jimi*, *Leptodactylus troglodytes*, *Physalaemus cuvieri*, and *Physalaemus kroyeri* were also identified in the Mata de Cazuzinha, but only on the edge, where they used waterbodies formed after the rains. We believe that

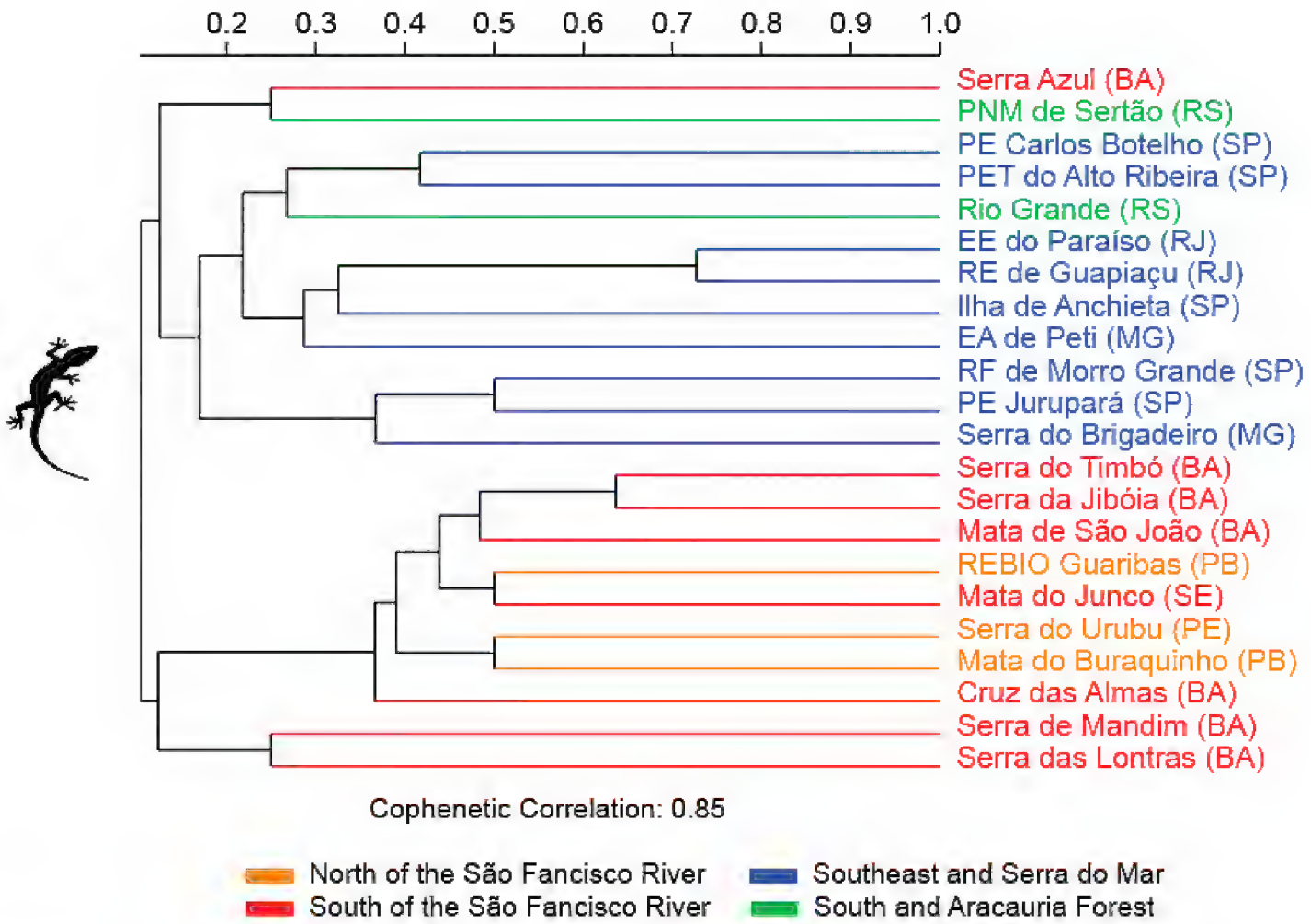

Figure 10. Dendrogram of cluster analysis (Jaccard Indices) of the lizard species composition from 22 localities in Brazilian Atlantic Forest. Abbreviations in Materials and methods.

P. paulodutrai's dominance of the urban forest fragment is due to the absence of waterbodies inside the fragment, which may have limited the permanence of other species.

The reptile species richness of the Cruz das Almas assemblage corresponds to 12.5% of the known reptile richness for the Atlantic Forest (Tozetti et al. 2017) and to 4.9% of the known species richness for Brazil (Costa and Bérnils 2018). Considering the taxa individually, for the Atlantic Forest, the lizards richness corresponds to 17.9%, that of snakes to 10%, that of amphisbaenians to 9.1% and that of testudines to 21.4% (except for *Trachemys dorbigni*) of the biome richness, while for Brazil, the lizard richness corresponds to 5.4%, that of snakes to 4.7%, that of amphibians to 2.8% and that of testudines to 5.5% (Tozetti et al. 2017; Costa and Bérnils 2018). Attempts to compare the richness of reptiles identified in the Cruz das Almas assemblages with the richness of other assemblages of the Atlantic Forest of the Bahia State were hampered due to the lack of systematic inventories involving the different taxonomic categories. We noticed the presence of robust information for snakes, while the information was less common for lizards, evidencing the need for greater efforts to characterise the species of the group in the several phyto-physiognomies of the Atlantic Forest of the State.

For the lizards, our results revealed the presence of species previously recorded for Bahia State and the Atlantic Forest (Couto-Ferreira et al. 2011; Hamdan and Lira-da-Silva 2012; Freitas 2014). However, a comparison of the assemblage richness of Cruz das Almas lizards with that of other assemblages from the Atlantic Forest revealed a

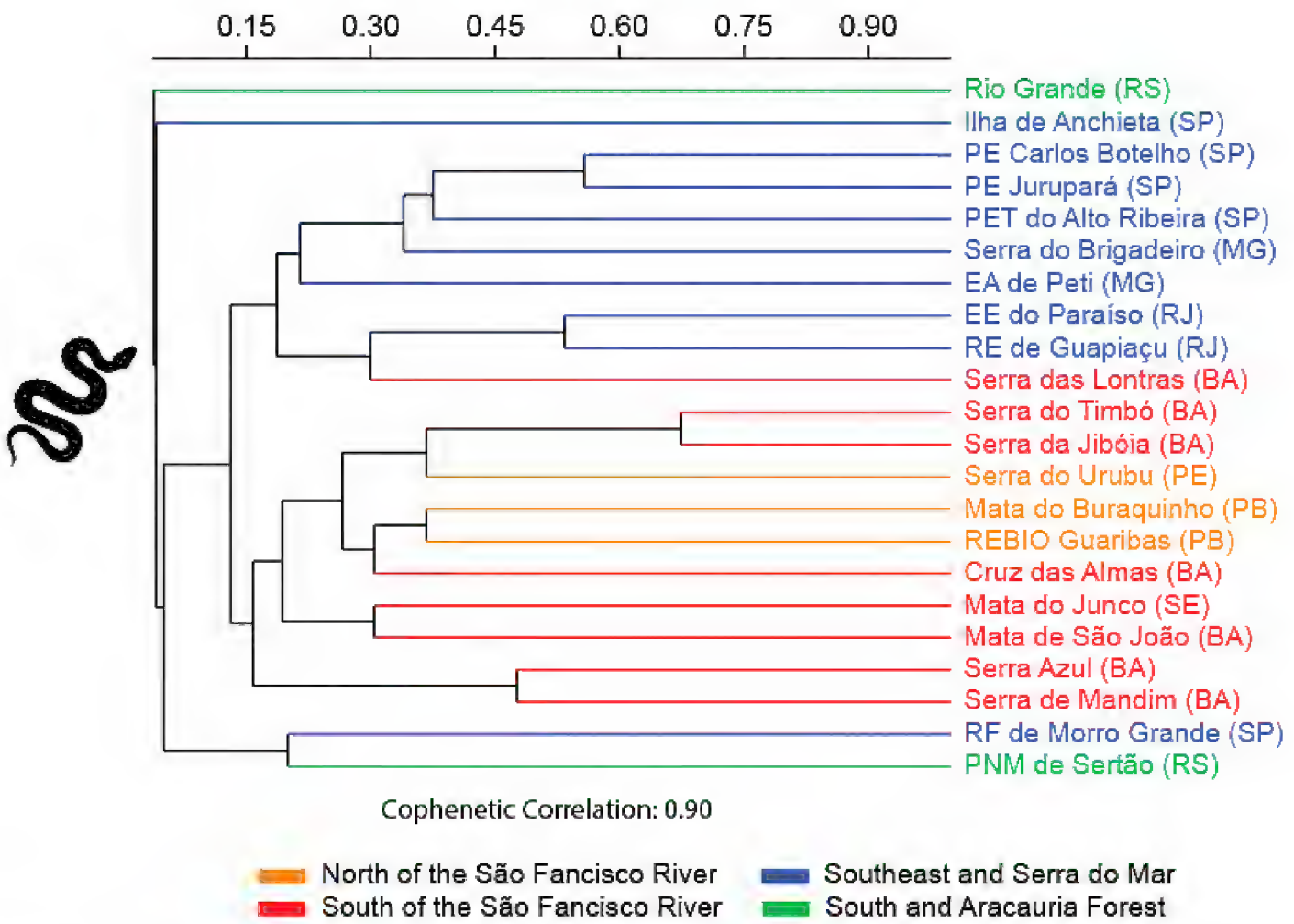

Figure 11. Dendrogram of cluster analysis (Jaccard Indices) of the snake species composition from 22 localities in Brazilian Atlantic Forest. Abbreviations in Materials and methods.

value similar to that of assemblages in the north and south of the São Francisco River (Santana et al. 2008, *n* = 13; Roberto et al. 2017, *n* = 16), while the value was higher in relation to several assemblages in the south and southeast of Brazil (Dixo and Verdade 2006, *n* = 5; Quintela et al. 2006, *n* = 8; Bertoluci et al. 2009, *n* = 5; Forlani et al. 2010, *n* = 10; Moura et al. 2012, *n* = 9; Almeida-Gomes et al. 2014, *n* = 10) and lower in relation to one assemblage north of the São Francisco River (Mesquita et al. 2018, *n* = 20). Observing the richness of only the assemblages within the State of Bahia, the richness found in the present study was inferior to the richness of lizards from the northern coast (Couto-Ferreira et al. 2011, *n* = 23), Serra da Jibóia (Freitas et al. 2018, *n* = 19), and Serra do Timbó (Freitas et al. 2019, *n* = 19). However, the richness of Cruz das Almas lizards was higher than that recorded for nine sand dunes of the southern and northern coast of Bahia (Dias and Rocha 2014, *n* = 4–11), mountainous forests in southern Bahia (Rojas-Padilla et al. 2020, *n* = 7), fragments of ombrophilous forest of southeast Bahia (Dias et al. 2014b, *n* = 3 or 4), and the semideciduous seasonal forest of southeast Bahia (Souza-Costa et al. 2020, *n* = 6). Although the richness estimators revealed that there are lizard species that have not yet been sampled in the Cruz das Almas assemblage, their values were low, indicating that there may be few species. Additionally, the dissimilarity between the Cruz das Almas lizard assemblage and other assemblages from the Brazilian northeast, in particular those that formed the largest group, may be associated with the absence of some species, such

as *Ameivula ocellifera*, *Enyalius bibronii*, *Enyalius catenatus*, *Gymnodactylus darwinii*, *Kentropyx calcarata*, *Polychrus marmoratus*, and *Tropidurus semitaeniatus*. These species are frequently found in inventory studies (see Roberto et al. 2017; Freitas et al. 2018; Mesquita et al. 2018), and their absence in the Cruz das Almas assemblage may have led to the pattern observed in our cluster.

Analysis of the species composition revealed two endemic species of the Atlantic Forest (*Phyllopezus lutzae* and *Dryadosaura nordestina*), which corresponds to 14.9% of the lizard fauna recorded in the study (Tozetti et al. 2017). The presence of *P. lutzae*, *Diploglossus lessonae*, and *D. nordestina* can be considered unusual records for Cruz das Almas. *Phyllopezus lutzae* has the type locality Salvador, the capital of the Bahia State (Loveridge 1941), and since its description, the species has been reported for areas of Atlantic Forest in northeastern Brazil, often associated with restinga environments and using bromeliads as microhabitat (Vrcibradic et al. 2000; Albuquerque et al. 2019). In Cruz das Almas, the species was found inside the forests, using bromeliads and tree trunks, in syntopia with the congener *Phyllopezus pollicaris*. In addition, the species was also found on the edge of the forest patches, on the trunks of trees that had epiphytic bromeliads and isolated in pasture matrices. This record represents the distribution of the species outside the restinga environment, with insertion in interior forest patches, and highlights the need for efforts directed at expanding information on the spatial distribution and behaviour of the species.

The lizard *Diploglossus lessonae* can be found in areas of Atlantic Forest and Caatinga in northeast Brazil (Vanzolini et al. 1980). Although the presence of this species is well documented north of the São Francisco River, reports for Bahia are limited to the municipalities of Feira de Santana, Miguel Calmon and Santo Amaro (see Caldas et al. 2016), with the last report in 2009 (ca. 12 years ago). It is possible that the scarcity of information on *D. lessonae* records for the Bahia State is associated with the secretive habit and burrowing behaviour of the species (Vitt 1985), requiring greater field effort. In Cruz das Almas, *D. lessonae* was found in habitat with slightly compacted soil and higher density of leaf litter, which is perhaps a characteristic of the essential habitat for the presence of the species. Finally, *Dryadosaura nordestina* is a species distributed in an area of Atlantic Forest of the Brazilian northeast. Although the occurrence of the species is well documented (Garda et al. 2014), information on populations in the State of Bahia is still scarce, and the species was included in the list of threatened fauna of the State of Bahia, in the vulnerable category (Sema 2017). A single individual from *D. nordestina* was found in Cruz das Almas, accessed through a pitfall trap in Mata de Cazuzinha. These data are different from the data of Lion et al. (2016), who pointed out *D. nordestina* as the most abundant species in small forest patches in the Rio Grande do Norte State. We believe that the increase in sample effort in more interior forest patches in eastern Bahia may reveal new records of occurrence of *Phyllopezus lutzae*, *D. lessonae*, and *D. nordestina*. Nevertheless, the encounter of *D. lessonae* and *D. nordestina* in the urban forest fragment highlights the importance of the preservation of the forest enclaves to maintain populations of these species.

For snakes, none of the species found in our study represents a new finding, as they are species that were previously registered in the State of Bahia and for the Atlantic Forest (Argôlo 2004; Hamdan and Lira-da-Silva 2012; Freitas 2014; Marques et al. 2016). Furthermore, *Bothrops leucurus* was the only species with a distribution endemic to the Atlantic Forest. A comparison of the richness of Cruz das Almas snakes with other assemblages of the Atlantic Forest revealed a similar value with several assemblages from north and south of the São Francisco River (Santana et al. 2008, n = 18; Marques et al. 2011, n = 15; Morato et al. 2011, n = 15) and south (Quintela et al. 2006, n = 16) and southeast Brazil (Araujo et al. 2010, n = 22; Vrcibradic et al. 2011, n = 19; Almeida-Gomes et al. 2012, n = 24). However, the richness value was lower than that observed in some snake assemblages in southeast Brazil (Condez et al. 2009, n = 46; Forlani et al. 2010, n = 48; Moura et al. 2012, n = 29) and north of the São Francisco River (Mesquita et al. 2018, n = 42). Within Bahia State, the snake richness of Cruz das Almas was lower than that registered on the northern coast (Marques et al. 2016, n = 50), Serra da Jibóia (Freitas et al. 2018, n = 37) and the southern and southeastern forests (Argôlo 2004, n = 61; Rojas-Padilla et al. 2020, n = 41) of the State. Moreover, the richness of snakes was greater than that obtained by Dias et al. (2014b) for four localities between the municipalities of Almadina, Floresta Azul, Ilhéus in southeast Bahia (5–8 species), and by Dias and Rocha (2014), who investigated the composition of snakes in nine localities of the sand dunes of Bahia (0–4 species). Nevertheless, the richness of Cruz das Almas snake species was similar to that obtained by Souza-Costa et al. (2020) for fragments of semideciduous seasonal forest in the Serras de Mandim and Azul in southwestern Bahia (13–18 species).

We believe that the difference in snake species richness between the assemblages of the Bahia State may be more associated with the sample design involved in the data collection than necessarily with a biological effect arising from the locality and study area. Dias et al. (2014b) performed a rapid inventory for data collection (12 days), which may have made it impossible to find seasonal or less abundant species, while Dias and Rocha (2014) only performed monitoring in restinga areas, not including other phyto-physiognomies, which may have reduced the sampling power only for species frequenting sand dunes. Similarly, the studies that showed high richness covered extensive areas, encompassing several municipalities and including different phyto-physiognomies (Argôlo 2004; Marques et al. 2016; Freitas et al. 2018). Thus, considering the existence of a directly proportional relationship between area vs. richness (Magurran 2004), it is possible that the size of the study area explains the variation in richness between studies and makes comparisons difficult.

Although we found a species richness similar to that presented by Souza-Costa et al. (2020), we noticed a difference in the composition of snake species, with the Cruz das Almas assemblage being dominated by species with a habit of living in open environments or being generalists in the use of habitat (Argôlo 2004), while there was a depletion of species more specialised to forested environments, typically of the genera *Corallus*, *Clelia*, *Dipsas*, and *Imantodes* and with previous records in the Serra da Jibóia (Freitas et al. 2018) and Serra do Timbó (Freitas et al. 2019), ca. 46 and 80 km from Cruz das Almas, respectively, and which we expected to be found in the studied area.

The lack of more specialised species in forest environments may help explain why the Cruz das Almas snake assemblage was more similar to the Mata do Buraquinho and REBIO Guaribas assemblages. The former is inserted in an Atlantic Open Forest ecosystem and is characterised by being a less dense forest with opened canopy (Marques et al. 2021). The latter is inserted in an ecosystem of Stational Semidecidual Forest and "tabuleiros", a type of vegetation of savanna similar to the Cerrado (Mesquita et al. 2018). Thus, these assemblages are subject to the dominance of species adapted to live in more open lands. As for the anurans, we believe that the absence of snakes specialised to forested environments that were expected to be found in the Cruz das Almas assemblage is an effect of anthropisation and habitat alteration, with the accentuated reduction and transformation of forested environments into cultivable areas and housing.

Finally, in this study, we report a new record of the water tiger *Trachemys dorbigni* for the Bahia State. The species is distributed throughout southern South America, in the countries of Argentina, Uruguay and Brazil, especially in the States of Rio Grande do Sul and Santa Catarina (Uetz et al. 2019). However, it is considered introduced into the Atlantic Forest (Tozetti et al. 2017) and has already been registered in the municipality of Salvador, capital of the Bahia State (Ecoa 2013). In Cruz das Almas, *T. dorbigni* was found wandering in a pasture area, with the presence of some sprawling residences. Thus, we do not rule out the possibility that the individual was being raised as a pet. Recent data have shown that Brazil has an intense reptile trade, which was enhanced by online shopping (Alves et al. 2019). In addition, the Recôncavo Baiano has a strong local trade of reptiles, with snakes being the main group traded (Macedo 2018). For Sy (2015) breeding reptiles as pets can promote the entry of exotic animals into ecosystems, and this is an extremely harmful phenomenon for native biota. Although we have no evidence that the presence of *T. dorbigni* in the studied assemblages comes from the trade of wild animals, we warn about the growth of the activity in the Recôncavo Baiano and the potential environmental damage that this entails, especially for ecosystems that are already heavily impacted.

The two amphisbaenian species identified in our study are common and frequently recorded in the Atlantic Forest inventories from the Brazilian northeast (Couto-Ferreira et al. 2011; Freitas et al. 2018; Mesquita et al. 2018). Despite the fossorial habit of the group, the number of species recorded in our study was similar to that recorded in other studies in the Atlantic Forest (Santana et al. 2008; Roberto et al. 2017; Rojas-Padilla et al. 2020). Perhaps the long-term fieldwork and the use of different methods of data collection have been important to record these organisms. Finally, the present study shows new data about the species composition of the herpetofauna in the Atlantic Forest of the east of Bahia, which helps to fill the information gap about the herpetofauna in unprotected areas. We highlight the prevalence of generalist species, typically associated with open lands and the presence of the threatened lizard *Dryadosaura nordestina*, as well as the invasive turtle *Trachemys dorbigni* in forest patches. This information can be helpful for characterising the fauna of this region and the factors involved in determining the composition of amphibian and reptile species in other assemblages in the Atlantic Forest of northeast Brazil.

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